hour. The following sample gives the incidence to the nearest lunar hour of the first few days in a year:—

Mean solar time. d. h.		Mean lunar time. d. h.
0 12	=	0 12
1 12	=	1 11
2 12	=	2 10
3 12	=	3 9
4 12	=	4 8
5 12	=	5 8
6 12	=	6 7
7 12	=	7 6
&c.		&c.

The successive 12h. of m.s. time will march retrogressively through all the twenty-four hours of m. lunar time.

Now, if starting from strip 0, we push strip 1 one division to the left, strip 2 two divisions to the left, and so on, the entries on the strips will be arranged in columns of approximately lunar time.

The rule for this arrangement is given by marks on a sheet of paper 18 in. broad; these marks consist of parallel numbered steps or zigzags showing where the ends of each strip are to be placed so as to bring the hourly values into their proper places.

At the end of a lunation mean solar time has gained a whole day over mean lunar time, and the 12h. solar again agrees with the 12h. lunar. On the guide sheet the zigzag which takes its origin at the left end of strip 0 has descended diagonally from right to left until it has reached the left margin of the paper, and a new zigzag has begun on the right margin.

When the strips are pinned out following the zigzags on the sheet marked M, the entries are arranged in 48 columns, but the number of entries in each column is different. The 48 incomplete columns may be regarded as 24 complete ones, appertaining to the 24 hours.

Harmonic analysis of the 24 means of the complete columns gives the required tidal constants. It must be remarked, however, that as the incidence of the entries is not exact in lunar time, investigation is made in the paper of the corrections arising out of this inexactness.

The explanation of the guide sheet for lunar time will serve, *mutatis mutandis*, for all the others.

The zigzags have to be placed so as to bring the columns into exact alignment, and printers' types provide all the accuracy requisite.

To guard against the risk of the computer accidentally using the wrong sheet, the sheets are printed on coloured paper, the sequence of colours being that of the rainbow. The sheets for days 0 to 73 are all red; those for days 74 to 74 + 73, or 147, are all yellow; those for days 148 to 148 + 73, or 221, are green; those for days 222 to 222 + 73, or 295, are blue; and those for days 296 to 296 + 73, or 369, are violet.

Thus, when the observations for the first 74 days of the year are written on the strips all the sheets will be red; the strips will then be cleaned, and the observations for the second 74 days written in, when all the guide sheets will be yellow, and so on.

The paper also gives another considerable abridgement of the process of harmonic analysis, which is independent of the method of arrangement just sketched.

In the Indian computation forms the mean solar hourly heights have been found for the whole year, and the observations have been rearranged for the evaluation of certain other tides governed by a time scale which differs but little from the mean solar scale. It is now proposed to break the mean solar heights into sets of 30 days, and to analyse them, and next to harmonically analyse the 12 sets of harmonic constituents for annual and semi-annual inequalities. By this plan the harmonic constants for 11 different tides are obtained by one set of additions. In fact, we now get the annual, semi annual, and solar elliptic tides, which formerly demanded much troublesome extra computation. A great saving is secured by this alone, and the results are in close agreement with those derived from the old method.

An abridged method of evaluating the tides of long period MSf, Mf, Mm, is also given. The method is less accurate than that followed hitherto, but it appears to give fairly good results, and reduces the work to very small dimensions.

The advantages of the method proposed in the present paper may be best realized by a comparison of the amount of work entailed in the reduction of a year's tides as it has hitherto been carried out by the Indian Survey at Poona, and what it will be under the new method.

It has been usual in the Indian reductions to use three digits in expressing the height of water, and there have been fifteen series, or even more. It follows from a simple multiplication that the computer has had to write 394,000 figures in reducing a year of observation. This does not include the evaluation of the annual and semi-annual tides, so that we may say that there have been about 400,000 figures to write.

It is now proposed to express the heights by two digits, and they only have to be written once, and the number of figures to write is 17,500; accordingly the writing of 382,000 figures is saved.

In the old method the computer had to add together all the digits written, say, 394,000 additions of digit to digit.

It is now proposed to use twenty-four hourly values in three series, viz. S, M, and MS, and twelve two-hourly values in eight others, and the number of additions comes to 123,000. Thus 270,000 additions are saved.

We may say that formerly there were about 800,000 operations (writing and addition), and that in the present method there will be about 140,000. This estimate does not include a saving of several thousands of operations in obtaining the tides of long period. It may therefore be claimed that the work formerly bestowed on one year of observation will now reduce at least five years, and that the results are equally trustworthy.

The manufacture of the computing strips of xylonite is rather expensive, but as it formerly cost in England rather more than £20 to reduce a year of observation, the cost of the apparatus will be covered by the saving in the reduction of a single year, and it will serve for any length of time.

The apparatus, together with computation forms, will be on sale with the Cambridge Scientific Instrument Company at a price of about £8.

It is proper to mention that Dr. Börgen has devised and used a method for attaining the same end as that aimed at in this paper. He has prepared sheets of tracing paper with diagonal lines on them, so arranged that when any sheet is laid on the copy of the observations written in daily rows and hourly columns, the numbers to be summed are found written between a pair of lines. This plan is inexpensive and has considerable advantages, but the chance of error is no doubt increased by the fact that the lines of addition are diagonal, and because figures seen through tracing-paper are comparatively faint.

THE HARVARD COLLEGE OBSERVATORY.

THE forty-seventh annual report of the director of the astronomical observatory of Harvard College, for the year ending October 31, 1892, by Prof. E. C. Pickering, has been issued. We reprint the following passages:—

The number of photographs taken with the eight-inch Draper telescope is 2777. The number taken in Peru with the Bache telescope is nearly two thousand, of which 601 have been received in Cambridge. The examination of these plates has as usual led to the discovery of a large number of interesting objects. Ten variable stars, U Delphini, S Pegasi, T Aquarii, R Crateris, R Carinæ, S Canis Minoris, S Carinæ, R Ophiuchi, X Ophiuchi, and Espin's variable star in Auriga in addition to the thirty-seven previously announced have the hydrogen lines bright in their spectra. Seven new variable stars have been discovered this year by means of this property. The number of stars of the fifth type has been increased by eight, making the total number now known of these objects forty-five. The hydrogen line F was shown to be bright in the spectra of six stars in addition to those already known. Photographs have been obtained of the spectra of eight planetary nebulæ showing bright lines. The spectrum of the nebula surrounding thirty Doradus is unlike that of other gaseous nebulæ. The star A. G. C. 20,937 has a somewhat similar spectrum. Five stars have been shown to have spectra of the fourth type. All of these peculiarities have been detected by Mrs. Fleming except in the cases of one of the known variables, one of the planetary nebulæ, and two of the stars of the fourth type, which were found by Mr. A. E. Douglass, in Peru, before the plates were sent to Cambridge.

The amount of valuable material accumulated with these instruments is continually increasing, and has proved useful in many cases in studying the history of newly-discovered objects.

© 1893 Nature Publishing Group

The brightness for several years past of stars suspected of variability has been furnished to various astronomers. Plates have been sent to the Lick and Amherst Observatories and to the Smithsonian Institution for special investigations. From one of them a new variable star in Aries was discovered by Prof. Schaeberle. It is hoped that this use of our plates may increase in the future. A large number of photographs were taken of the new star in Auriga. An examination of the older photographs showed that the region containing it had been photographed eighteen times from November 3, 1885, to November 2, 1891, and that it was then apparently fainter than the thirteenth magnitude. It appeared upon five plates taken between December 16, 1891, and January 31, 1892. After its discovery it was photographed on sixty-five chart plates and thirty-six spectrum plates, until April 6, when it became too faint to be visible in the encroaching twilight. All of these plates have been carefully studied and measured. Twenty-one charts and fifteen spectrum plates of this object have been taken since its reappearance in September, 1892. On these last plates, the spectrum is shown to resemble that of a planetary nebula.

Many photographs of the lunar eclipse of November 15, 1891, were taken both at Cambridge and at the Boyden observing station near Arequipa, Peru. The examination of these photographs for the detection of a possible lunar satellite led only to a negative result.

The number of photographs taken with the 11-inch Draper telescope is 996. They include 372 spectra of β Aurigæ to determine the law of periodic doubling of the lines. 244 of these images show the lines double so that the separation can be measured. In like manner 208 spectra of ζ Ursæ Majoris have been photographed, and in 49 of them the lines are separated widely enough to be measured. A similar study has been made of the new star in Auriga, of β Lyræ, of 11 Monocerotis, and of some other stars having peculiar spectra. Photographic charts have also been obtained of numerous variable stars, stars having large proper motion, clusters and stars having peculiar spectra to determine their parallax if it is perceptible.

BOYDEN DEPARTMENT.

In establishing the fund that bears his name, Mr. Boyden desired to secure an astronomical station where the effects due to the atmosphere would be greatly diminished. This has now been successfully accomplished in the Harvard Station at Arequipa, Peru, where the effect of the air is no longer as heretofore the principal obstacle to progress in astronomy. Instead of this the limit is now the size and excellence of our instruments. A great advance would probably be made in our knowledge of the planets, and perhaps of the fixed stars, if a telescope of the largest size could be mounted under such favourable conditions.

This station has continued in charge of Prof. W. H. Pickering. The instruments chiefly employed have been the 13-inch telescope, the 8-inch Bache telescope, and a photographic camera having an aperture of 2½ inches. The first of these instruments has been largely devoted to visual work, for which unusual advantages are afforded by the transparency and steadiness of the air at this station. Many interesting results have been derived from the observations made of the moon and various planets. The observations of the moon relate to Plato and other regions, which have been carefully examined, and also to the systems of bright streaks visible at full moon. The markings of Mercury have been studied, and this investigation appears to confirm Schiaparelli's view that the rotation of Mercury on its axis occupies the same time as its revolution in its orbit. Although this planet appears to have no atmosphere, the markings upon it are very faint compared with those upon the moon. Venus was micrometrically studied near its inferior conjunction with regard to its diameter, polar compression, and the refractive effect of its atmosphere. No permanent markings could be detected. An extensive series of observations was made upon Mars. The relative positions of 92 points upon its surface were determined by the micrometer. More than forty minute black points were discovered, provisionally designated as lakes. The polar compression of the planet was measured, and appeared to be greater than that indicated by theory, which may be due to an excess of cloud in the equatorial regions. The presence of the dark and narrow streaks called canals by Schiaparelli has been confirmed and various measurements of them have been made. The clouds projecting beyond the limb, and terminator, discovered at the Lick Observatory, have been studied, and their height has been found to be at least twenty miles. The relative colours of different portions of the planet have been minutely observed. Two large dark blue areas have been detected, and other portions have been noticed to be subject to gradual changes of colour.

Many new double stars were found in a survey of the heavens south of 30°, between 12h. and 18h. The August occultation of Jupiter was observed both visually and photographically, as was also the new star in Auriga and Swift's comet, the photographs of which showed detail not noticeable in the visual observations.

With the camera, having the aperture 2½ inches, very satisfactory photographs have been obtained of the Magellanic clouds, showing their composition to be partly of stars and partly of nebulous matter; also the spiral structure of the larger of the two clouds.

Meteorological observations are regularly carried on. Stations have been established at Mollendo, 100 feet above sea level, at La Joya, the elevation of which is 4,150 feet, at the observing station, 8,060 feet high, at the Chachani Ravine 16,650 feet high, where numerous miscellaneous observations have been made. Notwithstanding the great height of the last-named station, it can be reached by a mule path, and a hut has been erected where the observers can pass the night. A survey of the Arequipa valley and neighbouring mountains has been made, depending on two separate base lines. The heights of the mountains have been measured, and in some cases the result has been checked by a mercurial barometer.

THE BRUCE PHOTOGRAPHIC TELESCOPE.

This instrument, which if successful will be in many respects the most powerful in the world, is now rapidly approaching completion. The eight surfaces of its objective have been ground and polished so that it could be tested on a star. The results were satisfactory, although, of course, no definite opinion can be formed until the final corrections are applied. The focal length proved to be that desired within half of one per cent. Plans have been made and the foundations laid for a one-story brick building with a sliding roof, in which it will be erected during its trial in Cambridge. After this it is proposed to send it to the Arequipa station in Peru.

Photographs have been taken with the transit photometer on 192 evenings, and when clear, throughout the entire night. With this instrument images are obtained of all stars brighter than the sixth magnitude which cross the meridian during the night. The value of this work was illustrated when the new star in Auriga was discovered in February, 1892. It then appeared that this object had been photographed on twelve nights since December 10, 1891, while no trace of it was visible on thirteen plates covering this region and taken before December 2, 1891. The only knowledge that exists of its changes of light during the six weeks in which it remained undiscovered is furnished by these photographs and those taken with the 8-inch telescopes. It was also photographed with the transit photometer on twelve nights after its discovery. Of the forty thousand standard stars of the tenth magnitude about eight thousand have been selected by Miss E. F. Leland during the past year, making eleven thousand in all.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

OXFORD.—In the Chemical Department Prof. Odling is lecturing on the glucoses, Mr. Fisher on inorganic chemistry, Dr. Watts on organic chemistry, and Mr. Veley on physical chemistry. There are about sixty students working in the laboratories, and a few of the senior men are engaged in research.

Among the apparatus belonging to the late Duke of Marlborough, presented by the Duchess, are three large spectroscopes by Hilger, one having five prisms, another being a direct vision spectroscope 5 feet 6 inches in length, two balances by Deleuil; a mercury pump by Alvergniat, Dumas' vapour density apparatus, Thomson's electrometer gramme machine, large Rhumkorf coil and a quantity of valuable glass apparatus. There are besides a number of specimens of compounds of rare earths.

The Regius Professor of Medicine has placed his pathological

© 1893 Nature Publishing Group